A Comparison of MERRA-2 Cloud Water Data with Deep Convective Cloud Object Data over Tropical Oceans

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Motivation

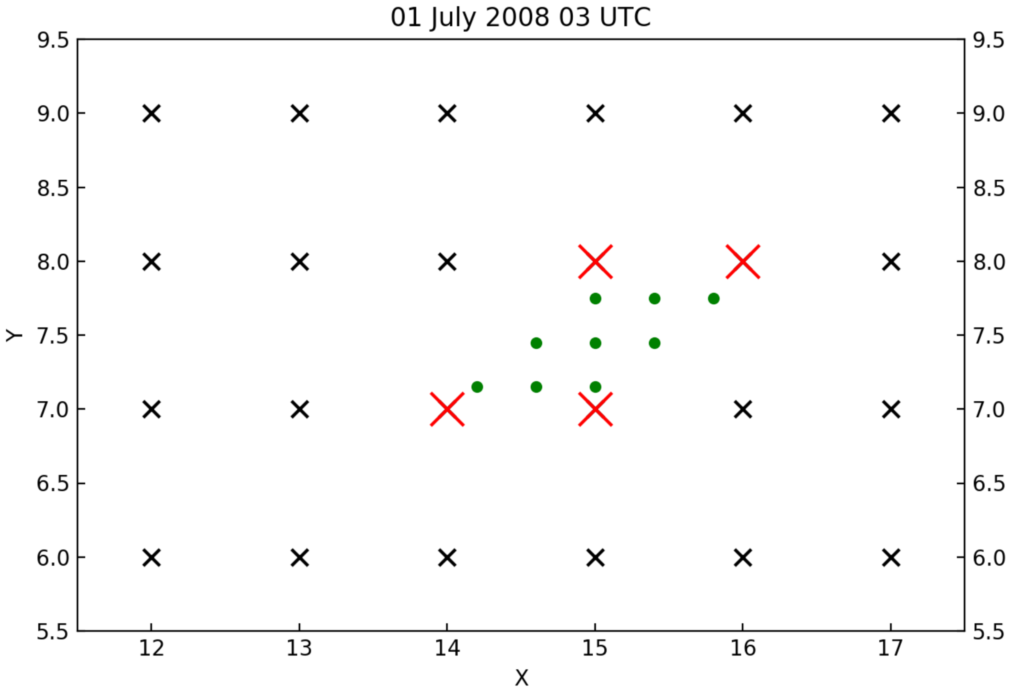
- Cloud systems (cloud objects) are influenced by the environmental conditions in which they form.
- How does the variability of temperature and humidity in the Tropics relate to macro-physical cloud properties and consequently the radiative heating rate profiles within a cloud system?
- First step: Comparison of cloud top height derived from cloud object and MERRA-2 cloud water fraction data

Some information about histograms and scatterplots

- All MERRA-2-derived object averages are the average of all unique MERRA-2 grid points closest to each cloud object footprint.
- All cloud object-derived object averages are the average of all cloud object footprints.

Selected MERRA-2 points: red crosses

Cloud object footprints: green dots



Some information about histograms and scatterplots

- Unless otherwise specified, comparisons include all cloud objects regardless of time difference between cloud object observation and MERRA-2 analysis time (time difference may be as large as 90 minutes)

- Cloud object data presented here are from Edition 2 CERES data

Methods to measure cloud top pressure

- CEP: Cloud effective pressure from cloud object data (CERES retrievals)
- CEP2: Cloud effective pressure estimated from MERRA-2 cloud water fraction (cloud water fraction ⟹ cloud optical depth ⟹ radiative transfer approx. ⟹ brightness T from radiance ⟹ effective pressure from effective T)
- SNDPRS: Cloud top pressure estimated from MERRA-2 sounding (EL: equilibrium level)

CEP2 – cloud effective pressure estimated from MERRA-2 cloud water fraction

Compute cloud effective temperature using discretized non-scattering radiative transfer equation:

$$U_1 = \mathrm{B}(T_0)\exp(-\Delta\tau) + B(T_1)(1 - \exp(-\Delta\tau))$$

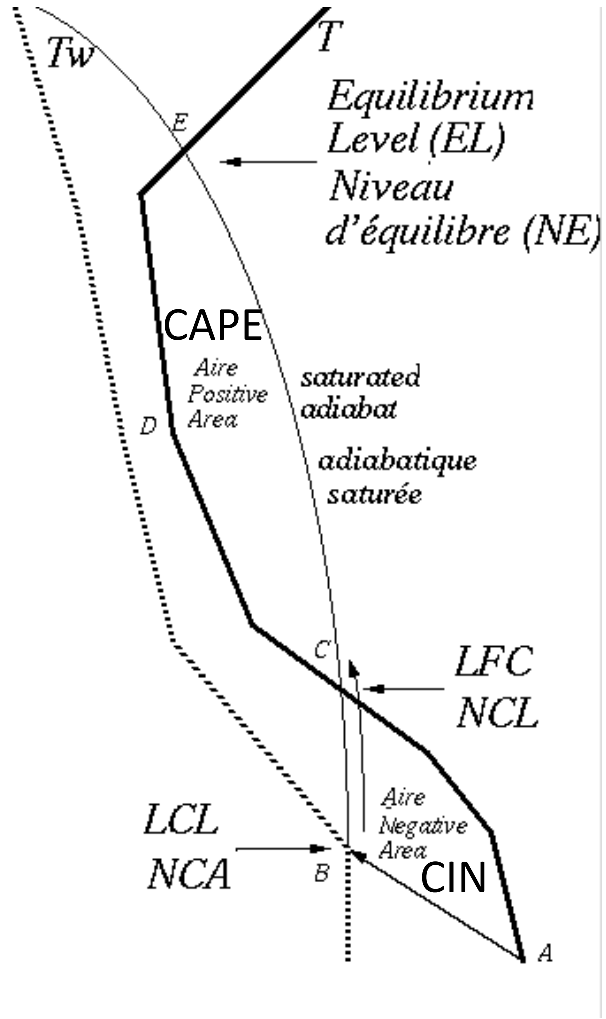
U_1 – Upward radiance from top of layer 1
$\mathrm{B}(T_0)$ – Emitted radiance from level 0 upward into layer 1
$(\Delta\tau)$ – Optical thickness of layer 1
$B(T_1)$ – Upward emittance from layer 1
$\exp(-\Delta\tau)$ – Transmittance of layer 1
$(1 - \exp(-\Delta\tau))$ – Emissivity of layer 1

Upward radiance converted to effective temperature via Planck function ($\lambda = 11\ \mu m$). Effective pressure estimated from effective temperature from MERRA-2 sounding.

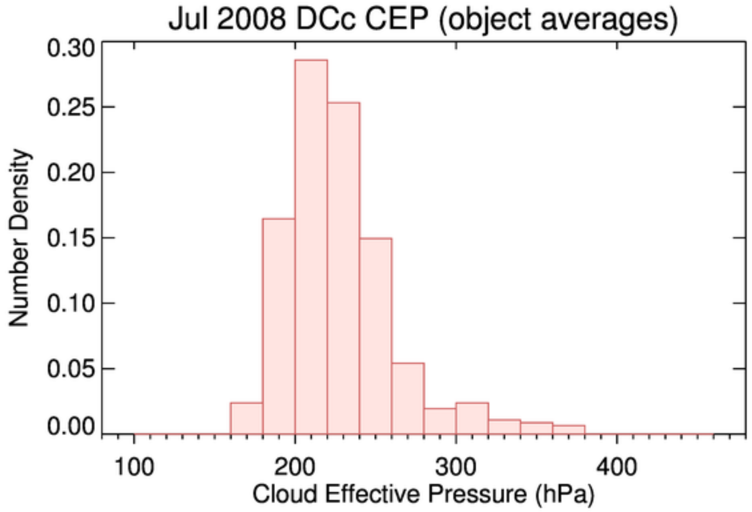
Cirrus visible optical depth (Heymsfield et al. (2003, JAM))

$$\tau_v = 9.31\times10^{-3}\times IWP(in\ gm^{-2})\left[1 + 71.7\times\left(1/r_{ge}\right)\right]$$
$r_{ge} = 1.11\times IWP^{0.56}$ (tropical cirrus effective radius)
$\sim 2 \times \tau_{IR} = \tau_v$

SNDPRS – cloud top estimated from EL

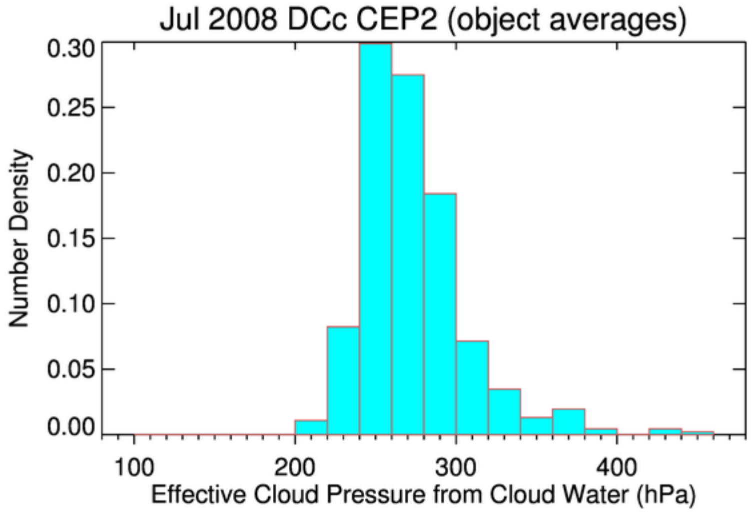


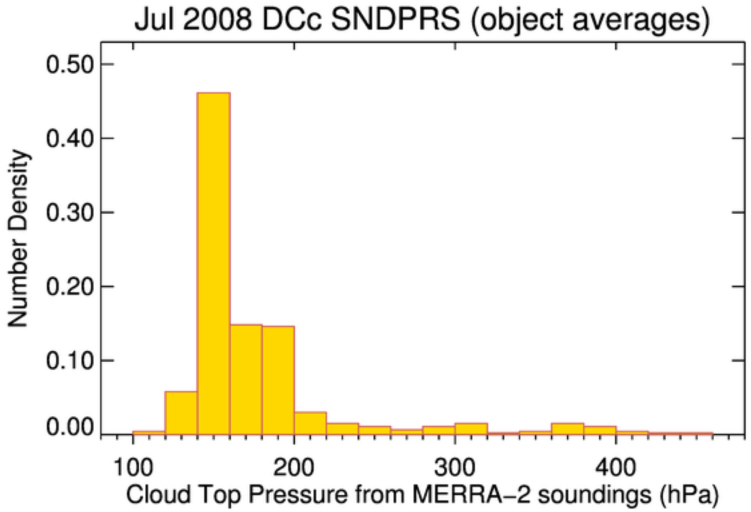
Object average histograms



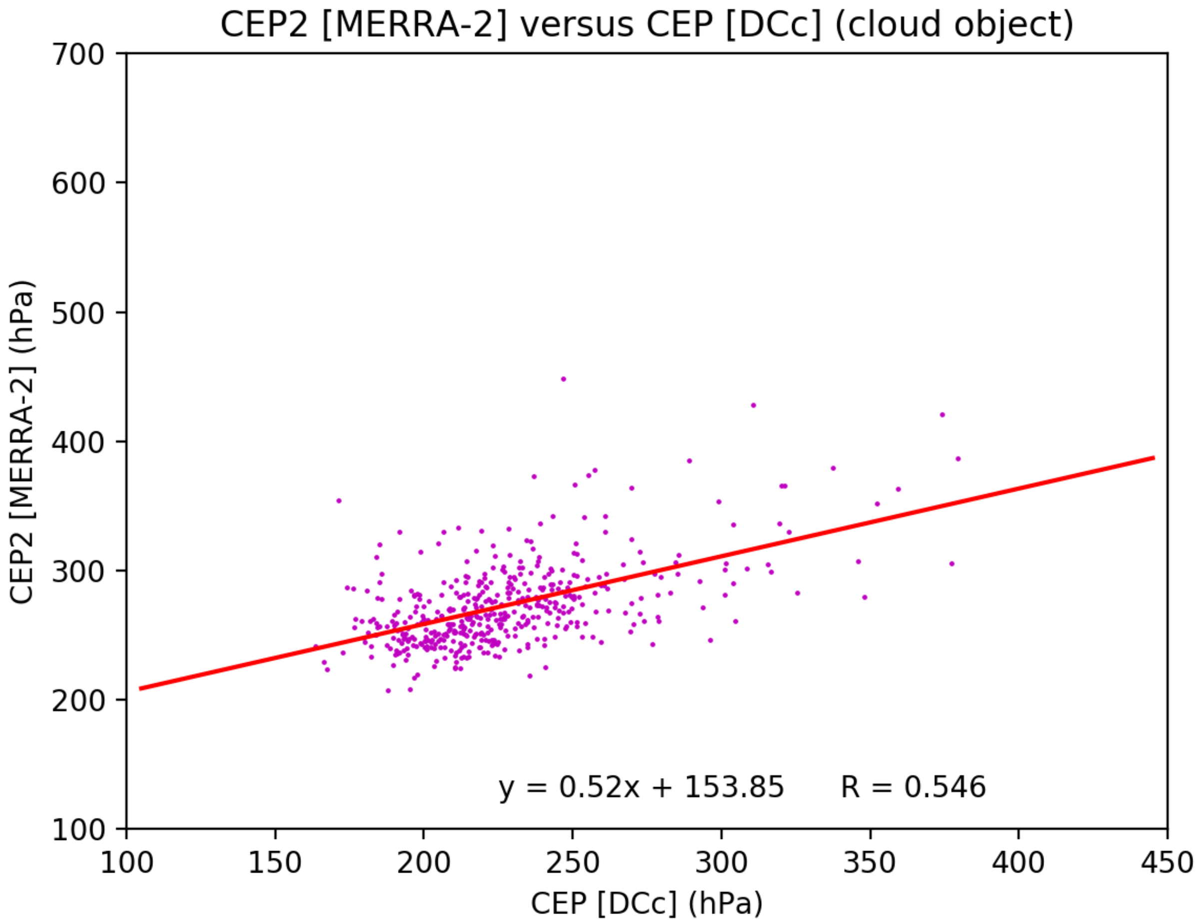
DCc (large deep convective objects)

Equivalent diameter: > 300 km





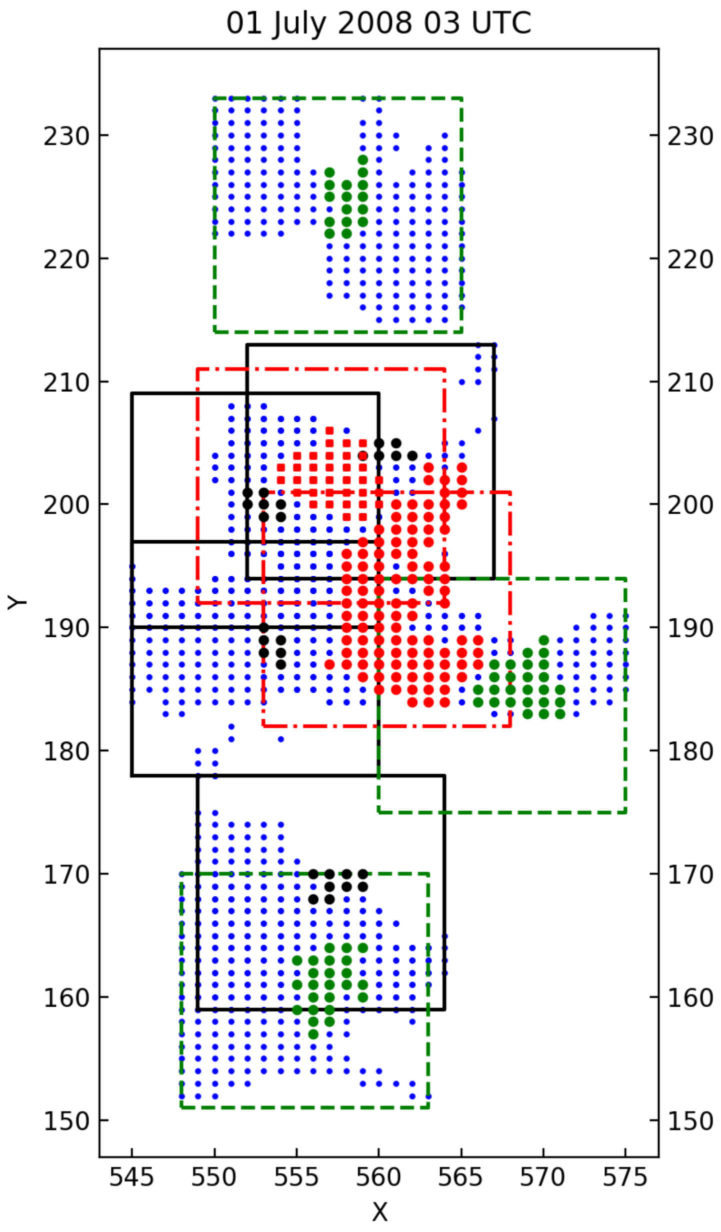
Object average scatter plots



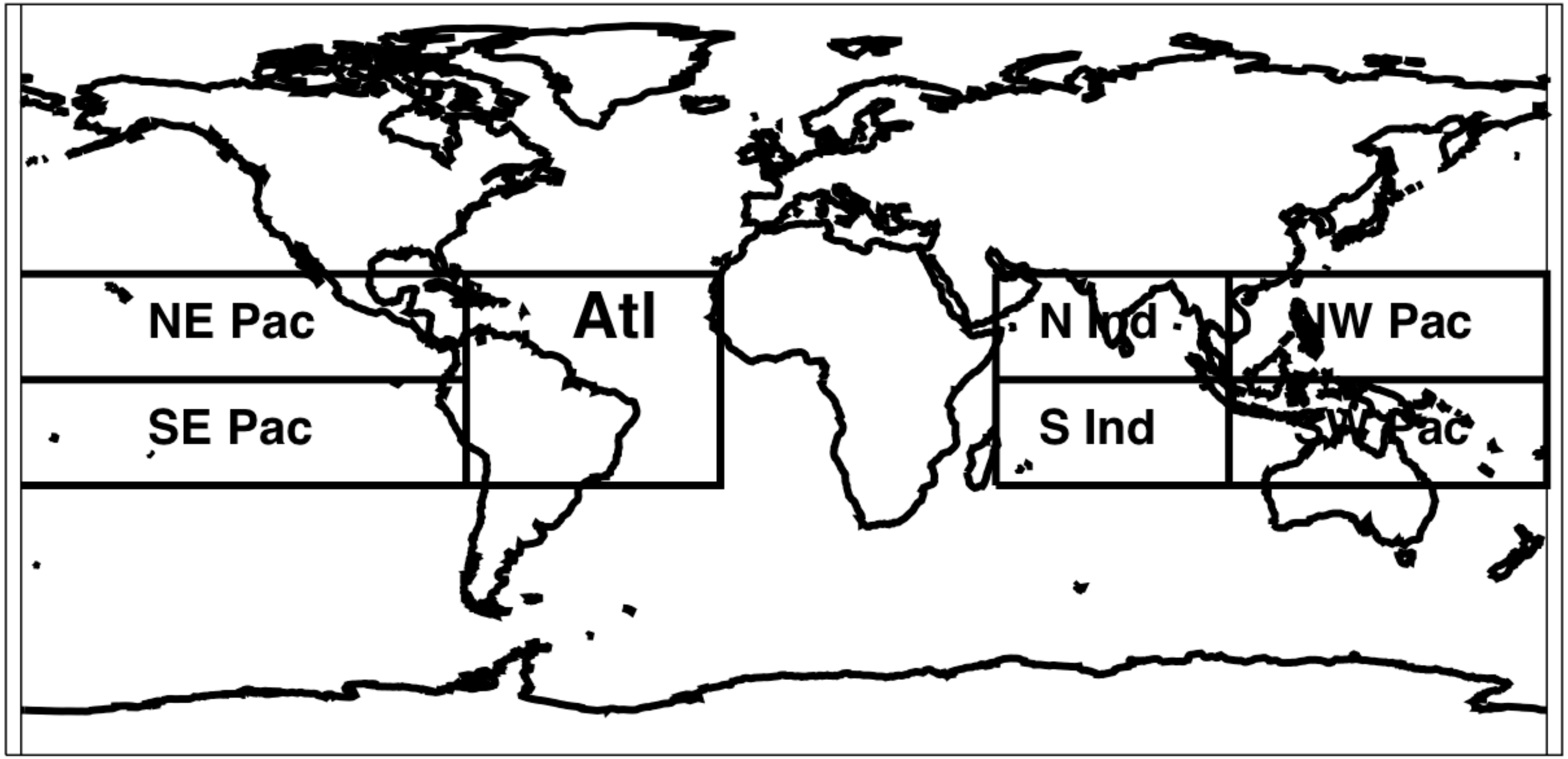
No improvement in correlations when selecting cloud object observations within 15 minutes of MERRA-2 analysis time.

Cloud objects often appear in clusters

- Nine cloud objects [4 small [Dca] objects, 3 medium [DCb] objects, 2 large [DCc] objects
- Blue dots represent MERRA-2 grid points where cloud water path (between 650 – 100 hPa) is greater than 50 g m^{-2} (τ_v = 2)
- Selected MERRA-2 points:
  in-cloud
- Points where cloud water path < 50 g m^{-2}:
  background



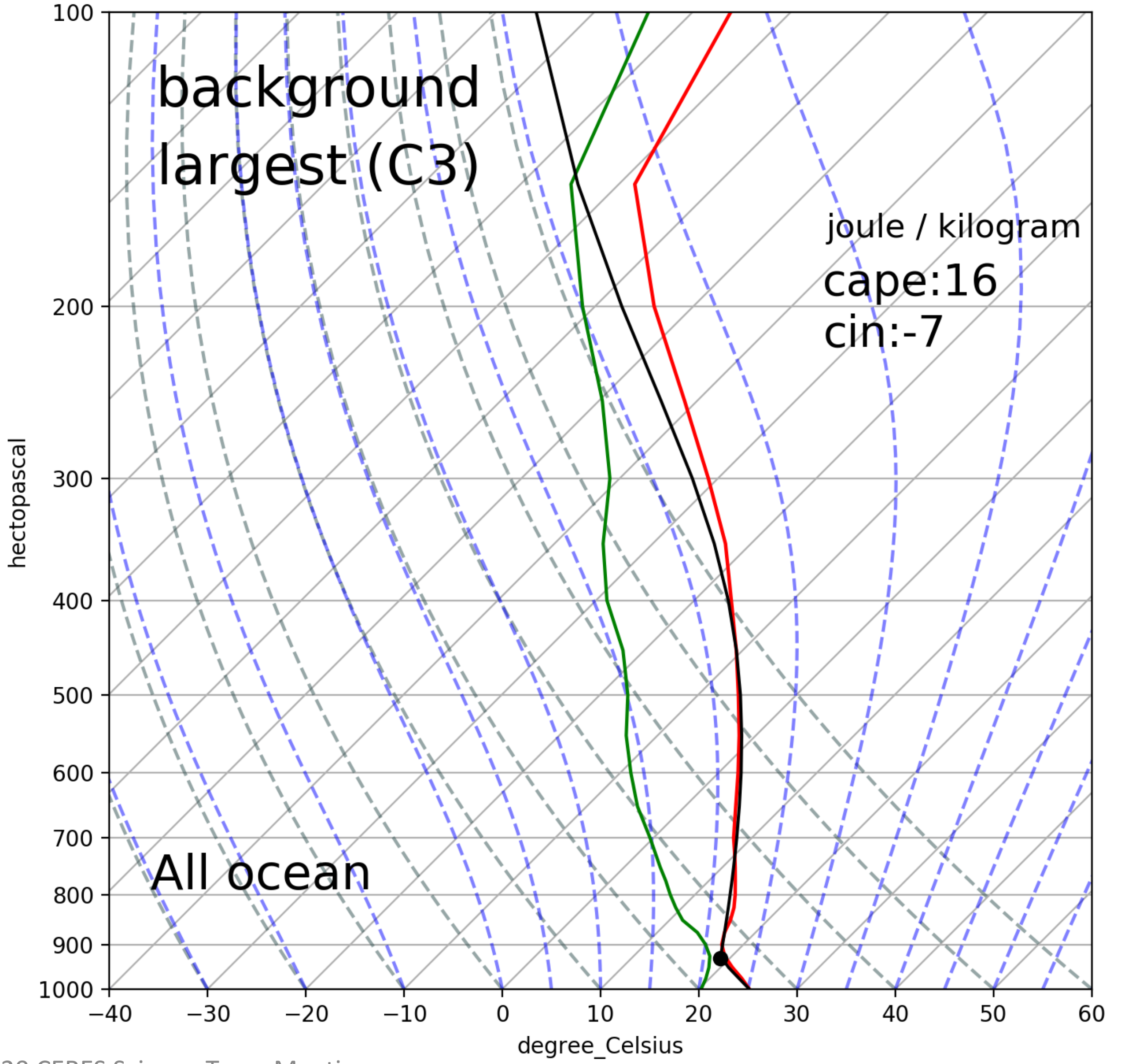
Oceanic cloud object regions



Cloud Object Size Categories

Category	Equivalent Cloud Object Diameter (km)	Number of cloud objects in this study/ Number of MERRA-2 profiles (in cloud)/ Number of MERRA-2 profiles (background)
A (small)	75 - 150	395 / 3,267 / 42,511
B (medium)	150 - 300	447 / 8,968 / 45,533
C1 (large)	300 - 450	165 / 8,007 / 15,119
C2 (larger)	450 - 650	110 / 10,336 / 9,015
C3 (largest)	≥ 650	80 / 16,416 / 3,078

Mean profile derived from MERRA-2 in-cloud points



Mean profile of surrounding MERRA-2 grid points (within ±5° of cloud object) where cloud water path is < 50 g m^{-2}

Summary and Future Work

- Monthly distribution of cloud effective pressure in deep convective cloud objects derived from MERRA-2 analyses (CEP2) is comparable to the cloud effective pressure retrieved from cloud object data (CEP). However, only a weak correlation found between scatter plots of CEP and CEP2 for individual cloud objects.
- Deep convective objects often have considerable overlapping of cirrus anvils. Mean MERRA-2 profiles within cloud objects are consistently more unstable and more humid than surrounding cloud-free regions, and cirrus anvils of largest cloud objects can fill most of the 10×10 deg grid boxes surrounding the cloud object.
- Compare MERRA-2-derived effective cloud height (CEP2) with CALIPSO data for large deep convective cloud objects.